LS-67
April, 1986

RACETRACK AT ANL

S. L. Kramer

LS-67
S. Kramer

RACETRACK AT ANL

Thanks to the assistance and patience of Albin Wrulich at LBL, the most recent version of the accelerator tracking code RACETRACK is now operational at Argonne on ANLHEP. Access to this program can be obtained by running the program HEP2:[AR.KRAMER.RACETRAC]RACE.EXE. An input file FOR005 and output file FOR006 are all that is required. A sample data file DEMO.DAT (Table I) and an instruction file RACETRACK.GUIDE are included in this directory.

This program has been tested in a mode which should agree with PATRICIA-84.9 for the "ideal" CDR lattice. Figure 1 shows the comparison of the dynamic aperture for both programs. The $\delta p/p = 0$ apertures agree exactly, while the apertures differ slightly for $\delta p/p \neq 0$. This mode tracks a single particle with starting coordinates: x, x' = 0 and $z = \sqrt{k\frac{\beta_z}{\beta_x}}\, x$, z' = 0 (z is vertical in RACETRACK). Since x can't be set equal to zero without making z = 0, this study approximated the x = 0 aperture limit by setting x small and k large $\left(x \approx 10^{-3}\ \text{mm and } k \approx 10^{6}\right)$.

In addition to the single particle mode, RACETRACK also has the ability to run multiple particles distributed on the boundary of an ellipse in both the horizontal and vertical planes. For each of n coordinates (x,x') on the horizontal ellipse, n particles are generated with (z,z') distributed on a vertical ellipse. For n particles specified in the INITIAL COORDINATE block, n^2 particles will actually be tracked. If any one particle fails to satisfy the stability criteria (i.e., remains inside the dynamic ($|x|$ or $|z| \leq 10^7$ mm) or the specified physical apertures for the required number of turns) then the amplitude of the x and z ellipses are reduced and tracking is attempted again. The amplitude of the z-ellipse is related to the x-amplitude by the emittance ratio k, as described above. The distributed version of RACETRACK required $n \leqslant 6$ particles but this has been modified in the ANL version to $n \leqslant 10$ (note: the distributed version did not warn the user if $n > 6$ was used and could therefore generate erroneous results). This option with 4×4 and 8×8 particles, yielded identical results to the single particle dynamic aperture in Figure 1. However, the multiple particle tracking will yield the smaller of the positive or negative horizontal apertures for distorted (nonsymmetric) apertures similar to that shown in Figure 1.

RACETRACK can also handle non-ideal elements by introducing zero length dipole kicks with systematic or random error fields. For dipole strength and roll errors, horizontal and vertical kicks can be introduced within the "ideal" dipole (with bend angle θ) which give an angular kick

$$\Delta x' = \theta \frac{\delta B_o}{B_o}$$

and

$$\Delta z' = \theta \alpha$$

where $\delta B/B$ is the strength error in dipole field and α is the roll angle from the vertical direction of B_o. Quadrupole placement errors can also be simulated in this same way, with an angular kick equal to the integrated dipole field resulting from quadrupole offsets δx and δz where

$$\Delta x' = K\ell \ \delta x$$

and

$$\Delta z' = K\ell \ \delta z$$

for K = the normalized gradient strength and ℓ = length of the quadrupole.

Figure 2 shows the results of the dynamic aperture for the CDR lattice with 10^{-5} errors ($\delta x = \delta z = 10^{-5}$ m, $\delta B_o/B_o = 10^{-5}$, $\alpha = 10^{-5}$ radians). The momentum errors tracked were limited to $\pm 1\%$, since the closed orbit finder had difficulty with dispersion (eta) calculations for the lattice with $\pm 2\%$ momentum errors.

RACETRACK also allows physical aperture to be set at any element in order to yield a nonlinear physical aperture limit for real or ideal accelerators. These physical apertures can be either rectangular ($|x| < a$ and $|z| < b$) or elliptical ($\frac{x^2}{a^2} + \frac{z^2}{b^2} < 1$). For comparison with PATRICIA and PATRIS, the rectangular apertures were set to be a = 30 mm and b = 20 mm at every sextupole, at the undulators and at the beta max quads Q2 and Q3. The resulting nonlinear physical aperture for the CDR lattice is shown in Figure 3. Attempts to run a 10^{-4} error lattice yielded closed orbit calculation problems even for $\delta p/p = 0$. Since the present version of RACETRACK doesn't have a correction (neither first turn nor distortion suppression) algorithm included, correcting the 10^{-4} error lattice wasn't possible.

RACETRACK is also able to track with synchrotron oscillations. At the end of each revolution or after each cavity, the momentum and phase of the particles (all particles have the same value) are changed and the linear and nonlinear elements are corrected for the change in normalized strength, which are then used for the next sequence of elements. Two tests were run on the CDR lattice with and without errors. The starting momentum error was 1% and phase equal to the synchronous phase $\approx 133°$ for $V_{rf} = 8.25$ MV and $U_o = 6$ MeV/turn. In both cases, the dynamic aperture was equal to the minimum aperture for $\delta p/p = \pm 1\%$ or 0, without synchrotron oscillations.

Table I RACETRACK Input Data for CDR Lattice

```
FLEXIBILITY  / 6 GEV LIGHT SOURCE
SINGLE ELEMENTS---------------------------------------------------
UND *  0                              3.0
WIG *  0                              3.0
D2  *  0                              0.35
D4  *  0                              0.375
D5  *  0                              0.71
D6  *  0                              0.29
D7  *  0                              0.50
Q1  *  2              .20283516       0.5
Q2  *  2             -.5283049        0.9
Q3  *  2              .5706265        0.5
Q4  *  2              .6495486        0.5
Q5  *  2             -.83111333       0.5
QH1 *  2              .5452074        0.5
QH2 *  2             -.8639510        0.9
QH3 *  2              .82033497       0.5
BND *  1 -.0400713                    2.45
SU1 *  3  -2.43640
SU2 *  3   2.63150
SH1 *  3  -1.59685
SH2 *  3   1.36340
SD2 *  3   2.04120
SF  *  3 -2.3206097
SD  *  3 1.7831364
SAP *  3  .0
SU3 *  3  .0
SH3 *  3  .0
MON *  1
CX1 *  1
CY1 * -1
NEXT
BLOCK DEFINITIONS------------------------------------------------------
  1   1
UND  UND
D2   D2
D4   D4
D6   D6
D5   D5
D7   D7
B12  Q1   D2
B23  Q2   D2
B34  Q3   D4
BB5  BND  D5
B47  Q4   D7
B58  Q5   D7
B46  Q4   D6
BB4  BND  D4
B33  QH3  D2
B22  QH2  D2
B11  QH1  WIG
B12- D2   Q1
B23- D2   Q2
B34- D4   Q3
BB5- D5   BND
B47- D7   Q4
B58- D7   Q5
B46- D6   Q4
BB4- D4   BND
```

Table I (continued)

```
B33- D2   QW3
B22- D2   QW2
B11- HIG  QW1
NEXT
STRUCTURE INPUT-----------------------------------------------------------
      8*( SAP
          UND  MON  B12  SU1  CX1  D2   MON  B23  SU2
          D2   MON  B34  SU3  CY1  D4   MON  BB5  SD   CY1
          D6   MON  B47  MON  B58  SF   CX1  D7   MON
          B58  MON  B46  SD2  CY1  D5   MON  BB4  SW3  CY1
          D4   MON  B33  SW2  D2   MON  B22  SW1  CX1
          D2   MON  B11  B11- MON  D2
          CX1  SW1  B22- MON  D2   SW2  B33- MON  D4   SW3
          CY1  BB4- MON  D5   CY1  SD2  B46- MON  B58-
          MON  D7   CX1  SF   B58- MON  B47- MON  D6
          CY1  SD   BB5- MON  D4   SU3  CY1  B34- MON  D2
          SU2  B23- MON  D2   CX1  SU1  B12- MON  UND  SAP
          UND  MON  B12  SU1  CX1  D2   MON  B23  SU2
          D2   MON  B34  SU3  CY1  D4   MON  BB5  SD   CY1
          D6   MON  B47  MON  B58  SF   CX1  D7   MON
          B58  MON  B46  SD2  SW3  CY1  D5   MON  BS4  CY1
          D4   MON  B33  SW2  D2   MON  B22  SW1  CX1
          D2   MON  B11  B11- MON  D2
          CX1  SW1  B22- MON  D2   SW2  B33- MON  D4   SW3
          CY1  BB4- MON  D5   CY1  SD2  B46- MON  B58-
          MON  D7   CX1  SF   B58- MON  B47- MON  D6
          CY1  SD   BB5- MON  D4   SU3  CY1  B34- MON  D2
          SU2  B23- MON  D2   CX1  SU1  B12- MON  UND  SAP
        )
NEXT
PRINTOUT OF INPUT ---------------------------------------------
NEXT ----------------------------------------------------------
LINEAR OPTICS CALCULATION-----------------------------------------------
ELEMENT          120
NEXT
CHROMATICITY CORRECTION------------------------------------------------
SF           0.0
SD           0.0
NEXT
TRACKING PARAMETERS----------------------------------------------------
       1000
         25   29.54    -2.111
          5   -0.02     0.02
NEXT
INITIAL COORDINATES----RECTANGULAR-------------------------------------
          8    0.0     45.0        0.500
NEXT
LIMITATION OF APERTURE--(half apertures H - V in mm)-------------------
SF     RE  1000.      1000.
SD     RE  1000.      1000.
SAP    RE  1000.      1000.
SU1    RE  1000.      1000.
SU3    RE  1000.      1000.
NEXT
ENDE===================================================================
```

LS8DASUW 800 Meter 11/27/85

6-GeV Light Source $\mu_x = 2.204$ $\mu_y = 0.737$ S.L. Kra

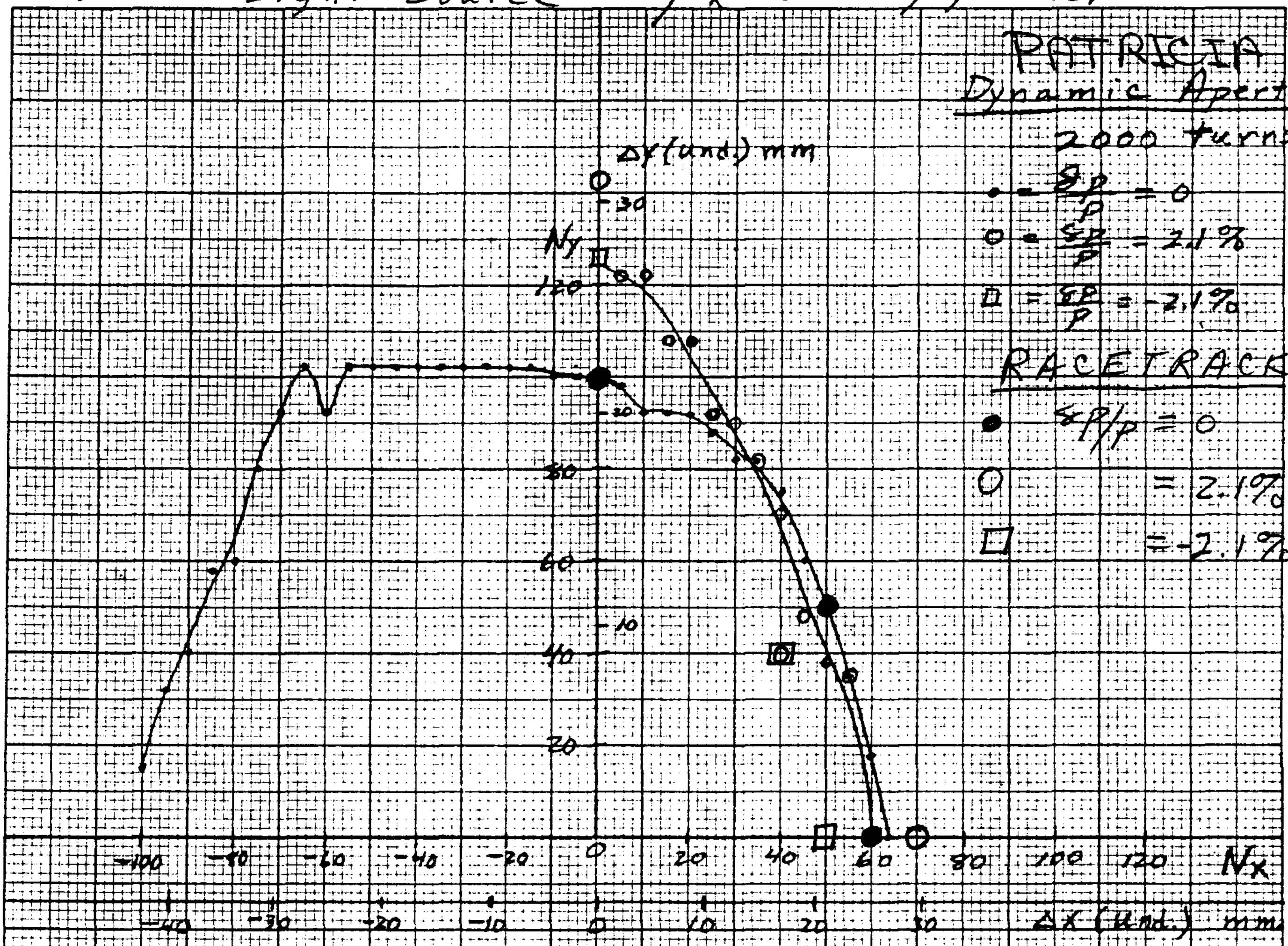


Figure 1 Comparison of Ideal Lattice

Dynamic Aperture for CDR Lattice

Fig. 2 Aperture for CDR LATTICE W 10^{-5} errors

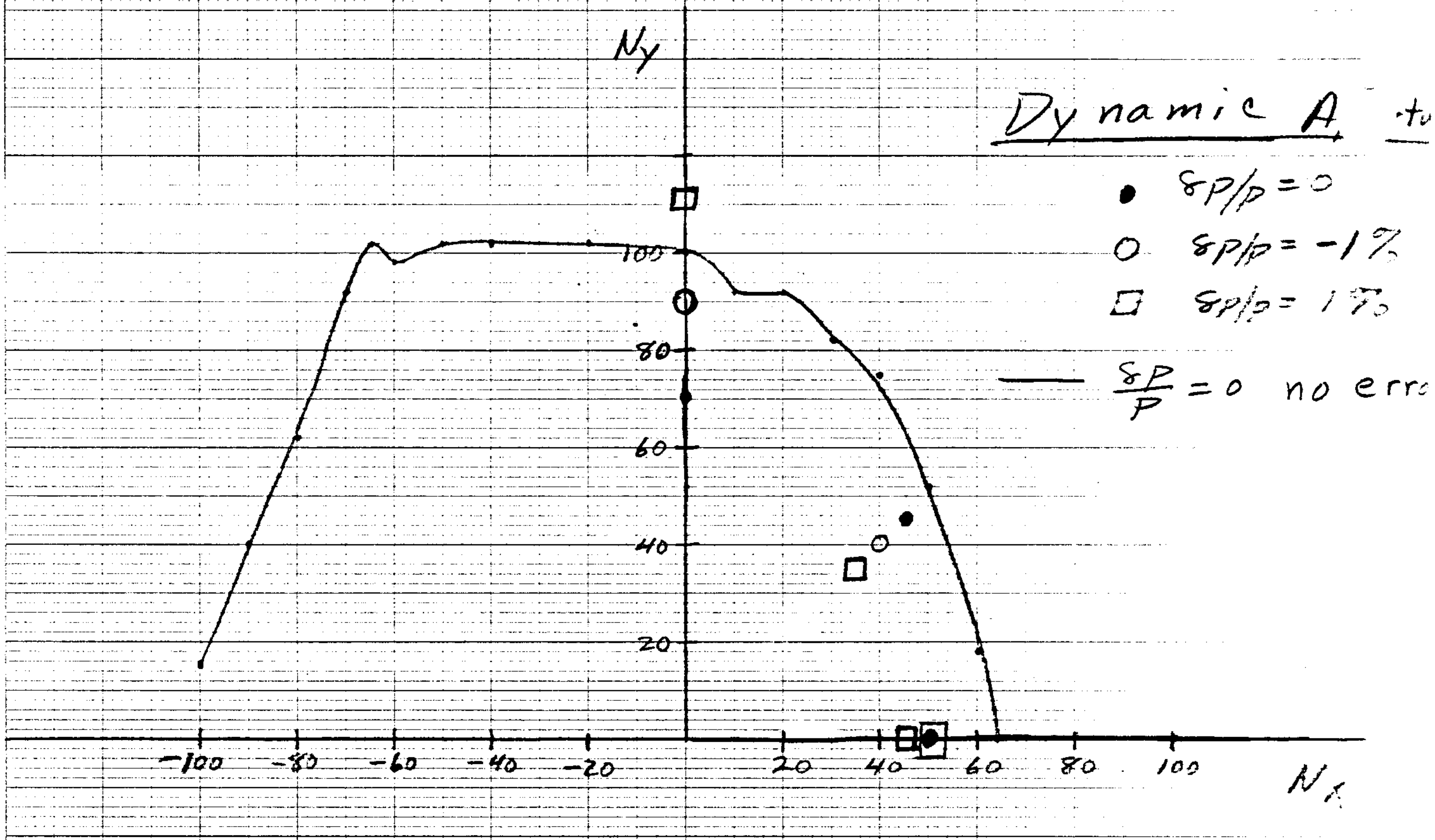
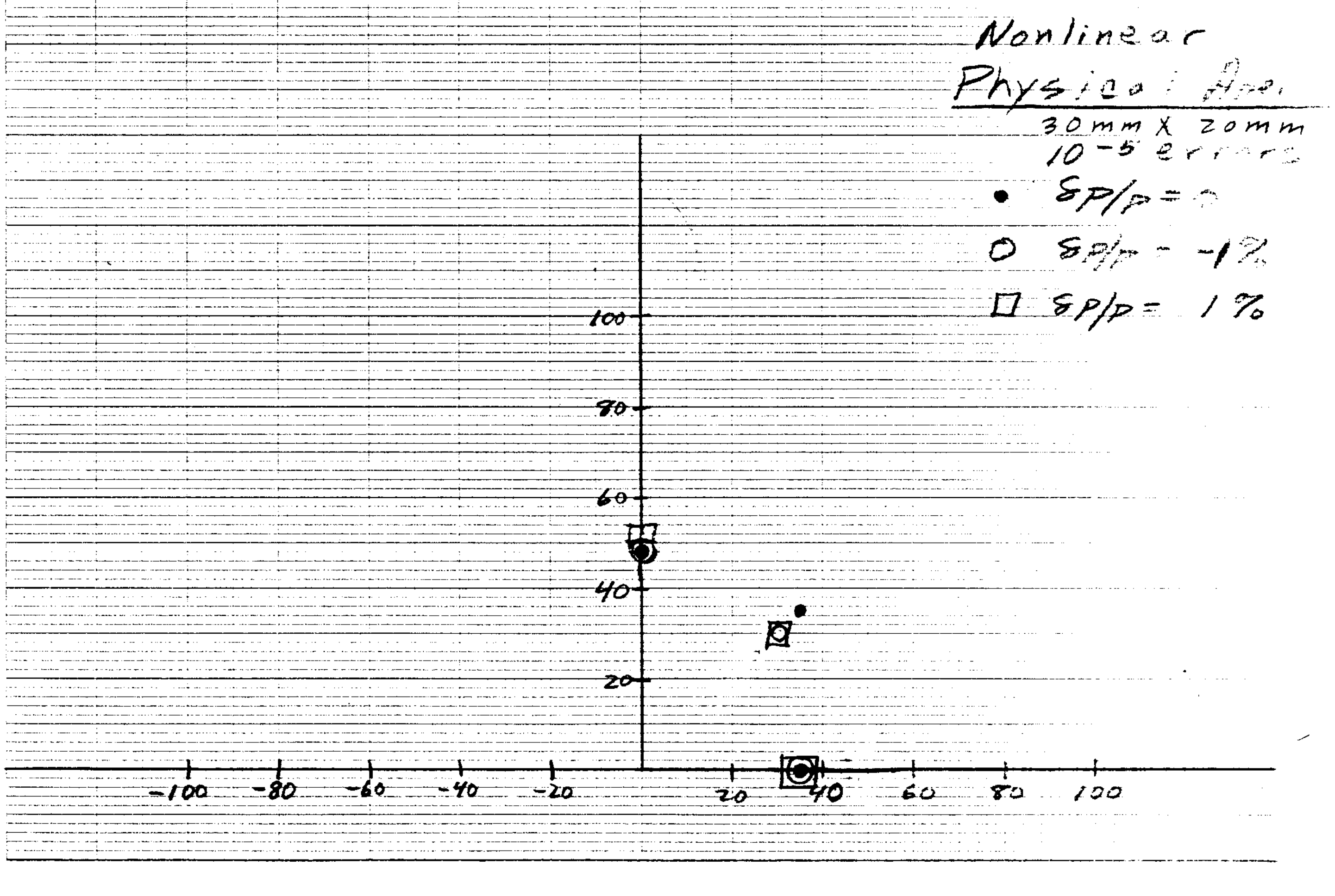


Fig. 3 Physical Aperture for CDR Lattice W 10^{-5} e



46 1331